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Overview of the Air-Ground Actions Two-Sided Engagement (AGATE) Simulation Model

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An overview of AGATE, a simulation model that
permits the user to examine alternative weapon
systems and battle plans in a combined arms
environment. The model is designed to measure
the impact of weapon systems characteristics,
organizational structure, doctrine and tactics,
and terrain and environment on the outcome of
battles. The tanks, armored personnel carriers,
artillary, air, and counterair systems that make
up the attack and defense combined arms teams
are brought together with their respective battle
plans to permit examination of the contribution
of each to the outcome of battles and firefights.
Programmed in FORTRAN IV, AGATE was developed as
a tool for use by operational planners and mili-
tary analysts in studying battle outcomes in-
fluenced by alternative mixes of weapon systems
and plans. It is particularly applicable to the
measurement of impact on air during the attacker
advance, deployment, and engagement phases of a
ground battle. 40 pp. (Refs.) (DGS)

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PREFACE

This report presents an overview of the Air-Ground Actions Two-Sided Engagement (AGATE) simulation model of combined arms battles. The model was built to fulfill the need for a fast-running, fine-grained, expected-value simulation that allows examination of alternative weapon systems and battle plans in a combined arms environment.

The tanks, armored personnel carriers, artillery, air, and counter-air systems that make up the attacker and defender combined arms teams are brought together with their respective battle plans to permit examination of the contribution of each to the outcome of battles and firefights.

The AGATE model was developed with the encouragement of the Office of the Assistant Chief of Staff/Studies and Analysis (AF/SA) as a tool for use by operational planners and military analysts in studying battle outcomes influenced by alternative mixes of weapon systems and plans. It is particularly applicable to measurement of the impact of air during the attacker advance, deployment, and engagement phases of a ground battle.

This overview report presents the AGATE model in sufficient detail to permit a planner or analyst to assess its scope. Detailed documentation, including the mathematical treatment, a user's manual, sample runs, and the AGATE FORTRAN code, is available from the author. The report was prepared under the Project AIR FORCE study effort "Improved Air-Ground Warfare Analysis Methods."

SUMMARY

AGATE is a dynamic, two-sided, expected-value, combat-interaction model of ground battle, including air attacks on ground targets and counterair defenses by ground forces. It is designed to measure the impact of (a) weapon system characteristics, (b) organizational structure, (c) doctrine and tactics, and (d) terrain and environment on the outcome of battles. The tanks, armored personnel carriers (APCs), artillery, air, and counterair systems that make up the combined arms team, together with the battle plans of each weapon system, are brought together in the model so that the contribution of each to the outcome of battles and firefights can be examined.

The model is programmed in FORTRAN IV and can be sized to simulate, at one extreme, the advance and series of firefights that make up the battle when a reinforced division attacks along several (4 to 6) interconnected avenues-of-advance against a brigade in defense; or, at the other extreme, it can be programmed to simulate the advance and firefight that occur when one attacking unit proceeds along a single avenue-of-advance and is opposed by one defense unit.

The ground battle consists of an advance by a column of attacking units, on each of several avenues-of-advance, that must fight their way through or around a series of defense positions, in depth, on the column's avenue-of-advance. The battle ends when the attacking column on each avenue-of-advance has been stalled, or when the attacking column on one avenue-of-advance, perhaps reinforced by units from another avenue-of-advance, successfully overruns the final defense position on the attacking column's avenue-of-advance.

When an attacking column of units encounters a defended position, the user-defined attack battle plan is evoked. This plan defines the attacker's action in case several sequential attacks are required for the attacker to overrun or bypass a defense position. The attack battle plan may consist of multiple applications of the following options for each firefight: (a) assemble a force from the advancing stream of armor units (tank, mechanized infantry) and launch an attack

against the defense position, (b) send a unit forward along a circu-
itous route and bypass the defense position, or (c) move forces later-
ally to another avenue-of-advance to reinforce the attacking stream
of units on that avenue.

The attacker's assault force is gathered from the stream of ad-
vancing units at an area protected from the defender's direct ground-
to-ground fires. The assault force consists of any user-defined com-
bination of tanks and mechanized infantry APCs. The mechanized
infantry units may advance with infantry aboard the APCs, or the in-
fantry in some units may be dismounted and advance with or be followed
by tanks and/or APCs. Dismounted infantry may fire small arms and
antitank guided missiles (ATGMs) as they advance. Direct-fire weapons
exchange fires as the assaulting force advances. Air on both sides
can attack enemy units during the assembly time, the advance, and the
assault as the user instructs. Indirect artillery fires can be em-
ployed by both sides for the length of time and quantity specified by
the user.

The defender in each firefight can be user-instructed to stay and
fight until (a) the attacker closes to the position or (b) until the
attacker closes to a user-defined range; he can then withdraw to a
reserve position.

The attack is launched when the attacker gathers the user-defined
attacker-to-defender force ratio at the protected area. Fires are ex-
changed between the attacker and defender, and the outcome of the fire-
fight is computed.

If the defender retains the position, the attacker can initiate
a second assault or choose any of the other assault options. If the
attacker overruns the defense position, any attacking armor units that
are still combat effective rejoin the attacker stream and continue in
the battle. The attacker's dismounted infantry that close to the po-
sition stay there and mop up rather than rejoin the battle. The de-
fender's infantry and armor that are overrun are removed from the
simulation.

Aircraft units can be introduced into the battle area at differ-
ent times to simulate their sequential arrival. Air strikes are

executed against targets assigned by the user-specified air-battle plan. Aircraft position and altitude are computed each 30 seconds of battle time to make the timing of attacks and reattacks consistent with the ground-battle timing and to determine when a flight is within range of an enemy antiaircraft firing unit. Air-to-air battles are not included in the simulation.

Attacks by aircraft, including fixed-wing, helicopters, and re-motely piloted vehicles (RPVs), produce a variety of effects on ground units in addition to attrition that may alter the course of the battle in several ways, including, for example, delays in gathering units for an attack. When aircraft attack ground units moving along roads, the effects may include user-defined delay of the unit because it had to stop alongside the road during an air attack; delay of the unit fol-lowing an air attack while damaged vehicles are pulled out of the way; attrition that forces a unit to abandon the road and move across coun-try at reduced speed; attrition that causes a ground unit to be removed from the force if the damage to the unit is enough to make it combat ineffective. When aircraft attack units that are moving across country, the effects include user-defined delays during the course of the attack; buttoned-up vehicles, reducing their ability to search for ground tar-gets; and an attrition level that forces a unit to abandon its advance.

The user designates which antiaircraft units advance, with or with-out other ground units, and which units are located in permanent posi-tions. Each antiaircraft unit fires at the aircraft that is closest to it and is within range.

The expected number of targets killed by each firing unit (air-craft flight, antiaircraft battery, tank company, antitank guided missile unit, artillery battery) is computed each 30 seconds of battle time. The number of targets killed by a unit is a function of the number of elements in the firing unit (e.g., the number of aircraft in a particular flight), the number of each type of target detected, and the weapon kill probability at the target range from the firing unit. The status (current strength, position, ammunition fired and remain-ing, and number of targets killed) of each unit is updated and can be

printed out each 30 seconds of battle time or at user-selected time intervals.

Terrain, weather, damage functions, other-situation data, and specific-case data may be stored on disk so that only changes between runs need be read in. The program consists of about 21,000 lines of code, and executes at about 200 times real time. For example, a 3-hour battle between a reinforced brigade advancing against two defending battalions requires about 1 cpu minute of computer time on an IBM 360-158. Core requirements are about 520 K bytes with no overlay.

CONTENTS

I. INTRODUCTION

The Air-Ground Actions Two-Sided Engagement model (AGATE) is designed to simulate combined arms battles in detail. Tanks, armored personnel carriers (APCs), artillery, air, counterair, and dismounted infantry systems that make up the combined arms team are brought together with their respective battle plans so that the user can determine how each affects the outcomes of battles.

The model was built to fulfill the need for a fast-running, fine-grained, expected-value simulation that permits examination of alternative weapon systems and battle plans in a combined arms environment. The driving force for such a model was the search for a new antiarmor versus armor doctrine that could cope with the problems that surfaced in the Yom Kippur war. There has also been a long-felt need for a balanced model that treats both air and ground systems in consistent ways and thus permits evaluation of each weapon system's influence on the outcome of a combined arms battle.

AGATE has the flexibility to test a variety of alternative battle plans that can aid in the evolution of workable antiarmor versus armor doctrines. It can also indicate changes caused by the introduction of new weapon systems, such as precision-guided attack weapons. Because it is a balanced model, the employment of air in the combined arms team can be examined while all the ground components of the team are in operation. Single-value indices used in many simulations to describe weapon system performance in combat have been abandoned in AGATE. Instead, the model uses the more basic performance parameters of each weapon system so that the effects of each parameter can be tested in the combined arms environment.

In the following paragraphs of this section we will discuss the background of AGATE, followed by a general description of the model. The remainder of the report will consist of a detailed description of the elements of the model. The ingredients of the scenario are outlined in Section II. They include a detailed treatment of the terrain, line of sight, weather-related inputs, and the kinds of units that the

model allows. The battle plans of the attacker and the defender are
discussed in Section III, together with policies for maneuvering
ground, air, and artillery units during the attacker's advance and in
subsequent firefights. In Section IV, we complete the description of
the battle to be simulated by outlining the series of operational and
weapon damage function inputs. Finally, in Section V, we outline the
conditions for (a) the exchange of fires among direct-fire ground-to-
ground weapons, (b) air-to-ground fires, (c) artillery indirect fires,
(d) mortar fires, and (e) ground-to-air fires, and then describe the
outcome of an infantry-to-infantry firefight.

BACKGROUND

The need for a model that would permit examination of battle
outcomes as affected by both battle tactics and weapons' performance
was clearly demonstrated in the early battles of the Yom Kippur war.
As the Egyptians crossed the canal at the start of the war, their
infantry used large numbers of antitank guided missiles in repelling
counterattacks by Israeli tanks. The tank units suffered heavy losses.
In subsequent counterattacks, the Israelis employed infantry to over-
run the Egyptian defending infantry before Israeli armor advanced.
Although the use of infantry to precede armor has been standard prac-
tice for a number of years, the idea of slowing the armor to wait for
the infantry to dismount and pave the way is counter to the widely
adopted doctrine that emphasizes continuous movement of armor forces.

This initial use of antitank guided missiles by infantry touched
off a reevaluation of the doctrines for the employment of tanks and
armored vehicles. A series of tests and studies in the United States
examined alternative tactics and doctrines. The results led to
General Donn Starry's observations on the tank/antitank guided missile
exchange in the January-February 1974 issue of the magazine *Armor*.
General Starry summarized observations gleaned from "a series of tests
and evaluations in the continuing search for the truth about the tank-
antitank battlefield." He observed that "It would be comforting to
say that the experiments confirm the old teachings, validating tactics,
techniques, organizations, equipments." He continued: "Such is not

the case: indeed the only bit of ancient dogma that remains unscathed is the essentiality of the combined arms team. Having acknowledged that fact, however, it may be that on the tank-antitank battlefield little recognizable remains."

AGATE was designed to assist in the examination of possible battles as doctrine continues to change when different families of weapon systems, such as remotely piloted vehicles (RPVs), attack helicopters, and mobile air defense units, are added to the tanks, APCs, infantry, and artillery of the combined arms team.

The need to handle ground and air weapon systems and battle plans in a balanced way within AGATE suggested that single-value indices of battle unit performance be abandoned. A variety of interrelated indices, including firepower scores, combat effectiveness indices, and weapons effectiveness indices, have been used in many battle simulations to measure battle outcomes, casualties, and front-line movements. These indices, as a class, imply the particular ways in which weapon systems are used and units are deployed and maneuvered in battle, which precludes the examination of alternatives. The development of consistent indices for dissimilar units has also presented unresolved difficulties, particularly when both air and ground units are used in the same simulation (e.g., in combat, how many aircraft are equivalent to a tank battalion fighting another tank unit?).

Instead of single-value indices with their implied battle plans and weapon system performances, AGATE requires that the user input battle plans and standard weapon data for each system. The user thus has control of all data and battle tactics necessary to test the contribution of each system to the outcome of battles and firefights in which combined arms are employed.

GENERAL DESCRIPTION OF AGATE

The AGATE simulation model may be used to measure the impact of weapon system characteristics, organizational structure, doctrine and tactics, and terrain and environment on air-ground interactions at the battle level.

The model simulates a course of events that may occur in battle as attacking units move forward, engage defending units in a series of firefights, and attempt to overrun the defenses. An interconnected series of avenues-of-advance allow attacking units (e.g., companies, flights, batteries) attempting to penetrate the defenses to be concentrated in a single avenue-of-advance, if alternative avenues are blocked and the user so specifies.

To operate AGATE, a user must define a setting for the battle, including all force elements, the battle policies of both the attacker and the defender, and the operational constraints. Battle policies include the way in which a final assault is to be conducted (e.g., dismounted infantry followed by tanks or accompanied by tanks) or the range to which the attacker may advance before a defending unit disengages and withdraws to a reserve position. Operational constraints include, for example, the fraction of a unit's strength at which the unit is no longer combat effective.

The user specifies the location and composition of each attack and defense unit at the start of the simulation. Attack units may all be started from assembly areas in each avenue-of-advance, be in column along the road in each avenue-of-advance, be moving across country, or any combination of these. The composition specified for each unit includes the number, type, and armament of vehicles, a sensor to detect targets, and the number of troops per vehicle (if appropriate).

As the attacking units advance, they may be subjected to defense fires that cause attrition and slow their rate of advance. An attacking unit may also be delayed by actions occurring closer to the defender. For example, attacking units moving along a road may be delayed while more forward units engage defending units in a firefight. When the attacking lead unit on an avenue-of-advance encounters a defense position, the attacker's user-defined firefight battle policy comes into play. The options are as follows: (1) Several attacking units may be gathered from the stream of units moving forward on the avenue-of-advance to form the attack force that engages the defender in a firefight. (2) The lead unit may be sent forward along a circuitous

route to bypass the defender. (3) All forces on the avenue-of-advance may move laterally to reinforce the attacking forces moving forward on an adjacent avenue-of-advance.

The user specifies the composition of the attack force gathered for the firefight. This force may be composed of all tanks, all APCs, all dismounted infantry, or any combination of tanks, APCs, and infantry. The ratio of the attack force's strength to that of the defender is also user-specified. When the attack force is assembled, the assault is initiated. Ground-to-ground and air-to-ground fires are exchanged, with each supporting unit's (air and artillery) fire being controlled by its user-defined battle-fire plan. As the attacker advances, the defender may withdraw to a reserve position when the attacker reaches a user-defined range, or the defender may stay and fight. If the attacker reaches the defense position, the "end game" or outcome of the firefight is computed. If the attacker is successful in overcoming the defense, the attacking units continue to advance. If the attacker is unsuccessful, the attacker's firefight battle plans are used to determine the subsequent course of events.

Each of the series of firefights that may occur during the course of the battle may involve all or any part of the weapon systems included in combined arms operations. Within AGATE, nine classes of units may fire weapons at targets (see Table 1). For example, tanks may fire at other tanks, APCs, antiaircraft vehicles, and infantry antitank positions. Infantry with small arms may, however, fire only at other infantry.

Within each class of units, specific types of vehicles and weapons may be included. For example, within the aircraft class, F-4's armed with guided missiles may be in one flight and helicopters armed with rockets in another. Within the tank class, M-60's armed with 105-mm guns may be in one unit, and T-62's armed with 115-mm guns may be in another.

The AGATE program is about 21,000 lines of FORTRAN IV code, not including common. The program has run on Rand's IBM 360/158 computer. It is written so that the array sizes of most of the variables may be expanded or contracted to suit the size of the problem. The

Table 1

WEAPON-TARGET PAIRS IN AGATE

Firing Weapons	Targets						
	Tanks	APC	Aircraft	Artillery	AA	Infantry	Infantry Antitank
Tanks	x	x	--	--	x	--	x
APCs	x	x	--	--	x	--	x
Air (direct fire)	x	x	--	x	x	--	x
Air (area fire)	x	x	--	x	x	x	x
Artillery	x	x	--	x	x	x	x
Antiaircraft	--	--	x	--	--	--	--
Infantry (small arms)	--	--	--	--	--	x	--
Infantry (antitank weapons)	x	x	--	--	x	--	x
Mortars	x	x	--	--	x	x	x

program executes at about 200 times real time. For example, in the case of a reinforced brigade attacking two deployed defense battalions, 3 hours of combat requires about 1 cpu second of computation time. Core requirements are about 520 K bytes. The component sizes are

	Bytes
Program	355,000
Common	130,000
Buffers, etc.	35,000
	520,000

II.   THE AGATE SCENARIO

The terrain on which a battle is to be fought, the weather exist-
ing at the time of the battle, the beginning forces employed by each
side, and their deployments and gross objectives are the basic ingre-
dients of what we call a scenario. As used in AGATE, the terrain data
define those areas, called zones, that have a direct line of sight
from each possible defense position and, within each, the fraction of
the targets that are not hidden by terrain features. The weather data
describe, as a function of range, the probability of detecting a target
with the particular sensor used by each observer. The forces are de-
scribed by defining the unit's initial location on the terrain; the
number, type, armament, and ammunition load for vehicles; the sensor
used to detect targets; and the number of troops per vehicle.

TERRAIN

The terrain in AGATE is divided into two areas (see Fig. 1):
(1) The region beyond the battle area, herein called the "flats" area,
consists of several avenues-of-advance, which, in this area, are only
roads leading from assembly areas up to the "hills" area. (2) The
battle area, which we call the "hills" area, lies between the flats
area and the main line of resistance; it consists of several avenues-
of-advance within which an attacker may advance along roads or deploy
and advance across country.

In the flats area, attacking units advance in columns along the
roads. This far to the rear, they are subject only to air and artil-
lery attack. The flats area extends a user-defined distance behind
the hills area (a nominal 20 km, for example).

Each avenue-of-advance in the hills area is composed of a road
running through a series of zones (as specified by the user). An at-
tacker may advance along the roads or across country. Associated with
each zone is a line of sight between that zone and each possible de-
fense located within that avenue-of-advance or in other avenues-of-
advance. Defense positions may be located only at "overwatch"
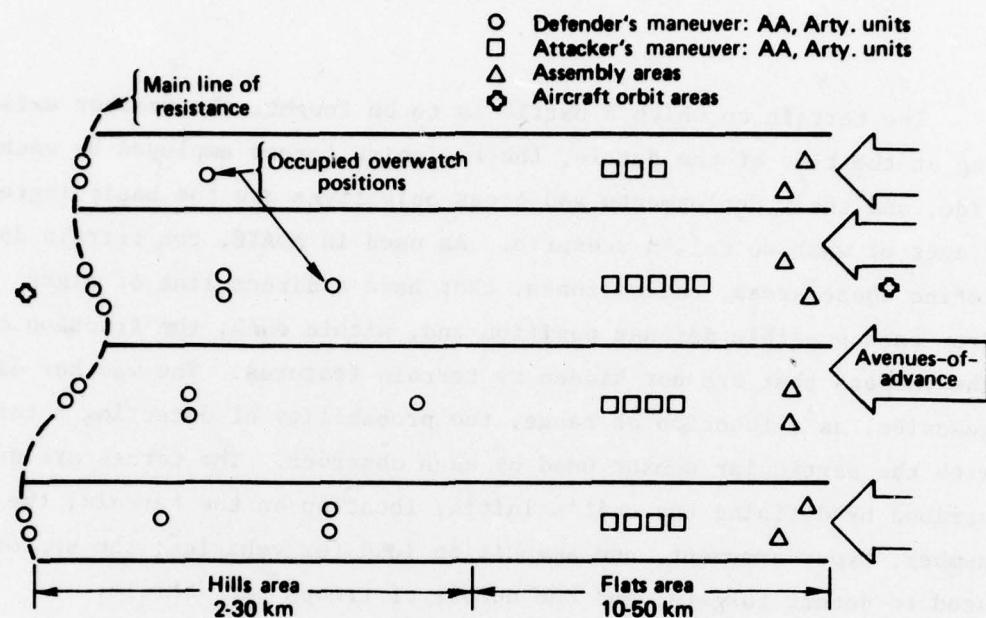
Fig. 1 — AGATE schematic of battle area

zones (see Fig. 2). Each line-of-sight function defines the fraction of vehicles within the zone for which a line of sight exists from the specified overwatch. The line-of-sight function also defines the fraction of vehicles that would be detected if the viewer had a perfect detection capability.

The width (parallel to the line of defense) of each avenue-of-advance is user defined, as is the depth of each zone. Each zone in an avenue-of-advance is simulated by a rectangle; the terrain and cover from each overwatch position are user specified. In determining firing ranges between firer and target units, each unit is considered to be located in the center of its avenue-of-advance, so that firing ranges between units in different avenues-of-advance include the effect of avenue-of-advance widths.

Within each avenue-of-advance, a zone may include a secondary route that the attacker may use to "bypass" any defense units located at a defense overwatch position without assaulting the defense unit.
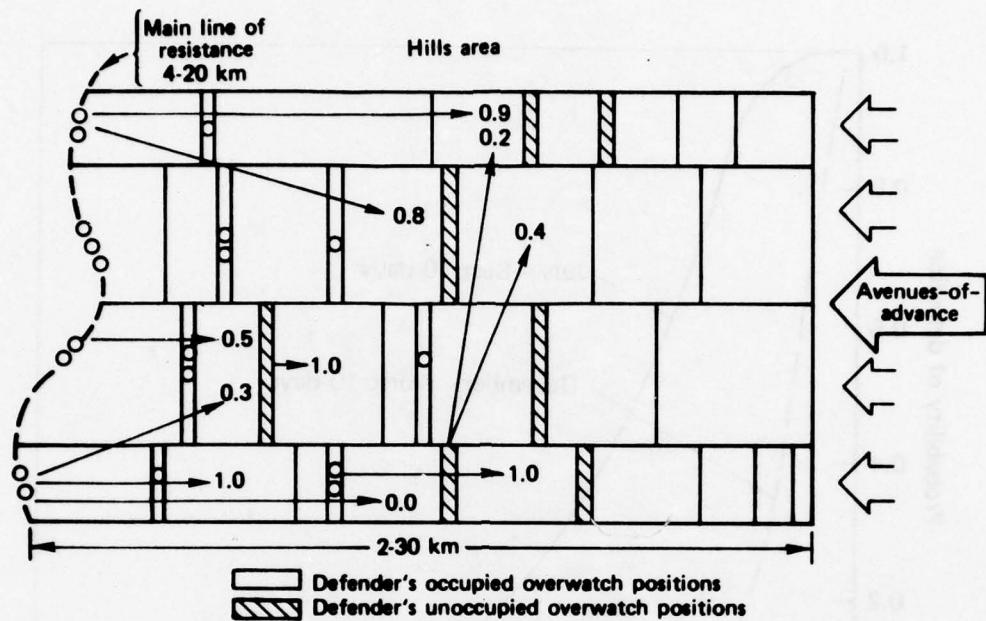
Fig. 2 — Illustrative defender's lines of sight and fractions of vehicles
in each zone visible from possible defense overwatch positions

Attack units using this bypass route advance at a fraction of the nor-
mal cross-country speed and enjoy a reduced line-of-sight function
(user defined) from defender units being bypassed.

WEATHER

Meteorological conditions in the battle area, in combination with
man-made camouflage, affect the ability of observers (firers) to detect
the presence of targets. In AGATE, we combine weather conditions and
camouflage and input the probability of detection as a function of
range for several "weather" conditions. For example, Fig. 3 illus-
trates the probabilities of detecting camouflaged tanks with an unaided
eye in Western Europe under average weather for the clearest 10 days
in July and for the worst 10 days in December (Ref. 2). Several types
of sensors, e.g., eyeball, infrared (IR), and radar, are permitted.
Each ground maneuver unit and air unit may have whatever sensor is
appropriate to the unit, so that mixtures of sensors are possible in
one battle.
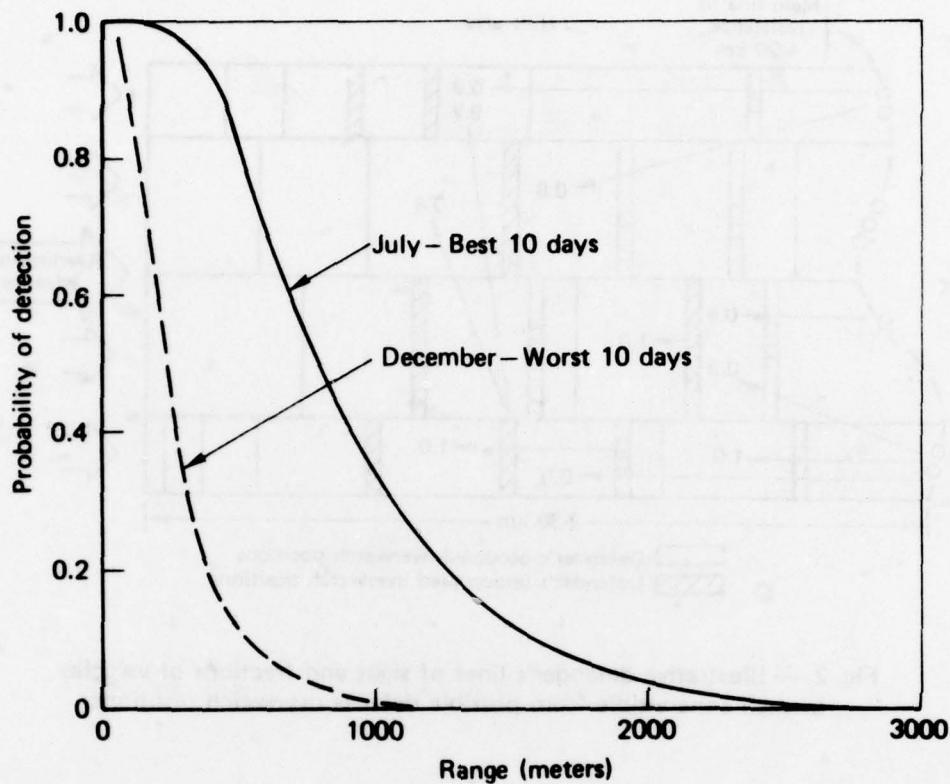
Fig. 3 — Probability of detecting a camouflaged tank
(Western Germany, unaided eyeball)

The effects of cloud height on aircraft operations are input in-
directly by using statements of flight altitude and attack maneuver
profile that are consistent with the hypothesized cloud conditions.

KINDS OF UNITS ALLOWED

AGATE processes five kinds of units: armor, mechanized infantry,
air, antiaircraft, and artillery units. A "unit" is the resolution
level of the model, and may typically be thought of as a company, a
battery, or a flight that operates with a consistent set of maneuver
constraints and behavioral parameters. Each unit is individually spec-
ified as to the number of vehicles (elements), weapon types (two

allowed), target sensor type (one allowed), vehicle type, and initial location (see Table 2). Composite operational forces are simulated by initially collocating units that define elements of such composite forces. For example, a tank-heavy company might be simulated as three collocated units that include a 10-tank unit, a 3-APC unit, and a 2-antiaircraft vehicle unit.

Tank Units

Tank units are sets of armored vehicles capable of cross-country operation. The vehicles within a unit operate together.

The user must specify the type of weapon aboard the vehicles (two types allowed) and the single type of target sensor used by the unit (for example, eyeball, IR, etc.). The user may also specify which of the permitted types of vehicles the unit will contain (one type allowed).

Table 2

DATA REQUIRED TO DEFINE A UNIT

Elements	Type of Unit				
	Tank	APC	Antiaircraft	Artillery	Air
Number of vehicles	x	x	x	x	x
Type of vehicle	x	x	x	x	x
Type of target sensor	x	x	x		x
Weapon types					
(1) Type	x	x	x	x	x
Rounds	x	x	x	x	x
(2) Type	x	x			
Rounds	x	x			
Number of infantry troops		x			
Infantry antitank weapons		x			
(1) Type		x			
Rounds		x			
(2) Type		x			
Rounds		x			
Mortars					
(1) Type		x			
(2) Rounds		x			

"x" = required data.

Artillery Units

Artillery batteries may be either self-propelled or towed. Several types of batteries may be defined. The number of vehicles/tubes and the number of rounds carried must be specified. Artillery operates only in the indirect-fire mode.

Antiaircraft Units

Two classes of antiaircraft units are allowed, mobile and fixed. The mobile units move with the advancing force. Within each class, several antiaircraft weapon types may be specified, but only one type is permitted in any given unit.

Air Units

Several classes of air units may be specified (e.g., fixed-wing, helicopters, RPVs). Within each class, several different vehicles (F-4, A-10, etc.) and alternative armaments may be specified in different units. For example, one air unit may consist of F-4's armed with electro-optical Mavericks, and a different unit may comprise F-4's armed with IR Mavericks. Area-coverage munitions, such as bombs, as well as single-target munitions, such as Maverick, may be specified. In addition to vehicle and armament types, each flight's entry speed, altitude, reattack flight profile, and exit speed and altitude must be specified.

APC Units

APC units are sets of armored infantry transporters with cross-country mobility.

The user must specify the vehicle type in the unit (one type allowed), the antitank armaments (two allowed) that the vehicle will carry (e.g., a light tank may have an antitank missile launcher and a 75-mm gun), and the single type of target sensor used by the unit.

The user may specify the number of infantry aboard each vehicle. The infantry are assumed to have their normal complement of small arms and machine guns, but the user may specify, in addition, two types of

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man-portable antitank weapons and one type of mortar. The user supplies
the number of antitank and mortar rounds.

When infantry is dismounted, an APC unit can become several units
(see Fig. 4): (a) vehicles that operate as a unit, and (b) infantry,
antitank, and mortar units that move as a group but are considered in-
dependently because they have independent vulnerabilities, rates of
fire, etc.

```
                    +------------------+
                    | Mechanized Infantry |
                    |       Unit        |
                    +------------------+
                             |
                             v
                    Dismount Infantry
                             |
        +----------+----------+----------+----------+
        |          |          |          |          |
  +-----------+ +--------+ +--------+ +--------+ +--------+
  | Empty APCs| |        | |Antitank| |Antitank| |        |
  | (with two | |Infantry| |Weapon  | |Weapon  | | Mortar |
  | types of  | | Unit   | | Unit   | | Unit   | | Unit   |
  |direct-fire| |        | |        | |        | |        |
  | weapons)  | |        | |        | |        | |        |
  +-----------+ +--------+ +--------+ +--------+ +--------+
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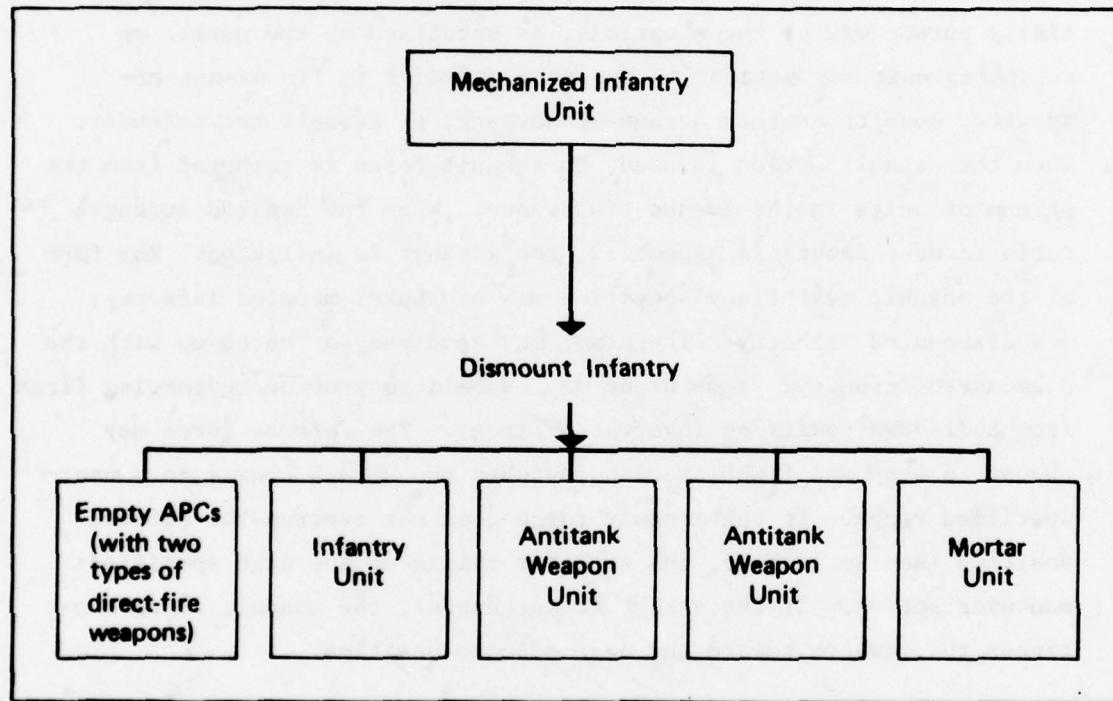
Fig. 4 — Mechanized infantry sub-units

III. BATTLE POLICIES

Air, artillery, and ground maneuver units in AGATE employ fire
and maneuver plans defined by the user. For air and artillery, these
plans include a series of target priorities for both the attacker and
the defender. The time at which each air unit is introduced into the
battle area may be specified so that sequential arrival can be simu-
lated. Artillery batteries fire when they come within range of tar-
gets in their target-priority list. Ground maneuver units proceed
along avenues-of-advance until they encounter defenses. They then ini-
tially pursue one of three options, as specified by the user: an
attacking unit may attempt to bypass a defender in its avenue-of-
advance, move to another avenue-of-advance, or assault the defender.
When the assault option is used, an assault force is gathered from the
stream of units in the avenue-of-advance. When the desired strength
ratio (a user input) is assembled, the assault is initiated. The form
of the assault may be any specified mix of tanks, mounted infantry,
and dismounted infantry. The armor may accompany or catch up with the
dismounted infantry. Some armor may be held to provide supporting fires
from hull-down positions (overwatch fires). The defense force may
choose to stay and fight or withdraw when the attack closes to a user-
specified range. If the assault force does not overrun the defense
position (see Section V), the attacker initiates the next specified
maneuver option. If the attack is successful, the assault force con-
tinues the advance toward the next defense position.

ATTACKER'S PLANS

Attacker's Advance Along an Avenue-of-Advance

The attacking units may be initially positioned anywhere along an
advance route from an assembly area in the flats to a position in front
of the most forward defense unit in that avenue-of-advance. Within the
hills area, units may either move along the road or across country.
When all units are placed in assembly areas, the time at which they are

to start the advance must be specified. An advancing force may be
spread along the advance route to simulate, for example, an advance
guard followed by the main body. At the other extreme, units may be
so positioned that they initiate attack of the defense's most-forward
position at the start of the simulation. As units advance, artillery
is deployed according to the input plan and may begin firing when ar-
tillery policy permits. Mobile antiaircraft units move forward within
the advancing stream of units in the sequence specified by the user.

The attacker's lead unit in each avenue-of-advance is designated
as the "first" unit. The attacker's first unit advances as the point
unit; it may fire at suspected defense positions on the next-most-
forward hilltop in an attempt to draw fire (reconnaissance by fire)
and advance against any opposition it encounters. If no opposition is
encountered, this first unit advances to the last hill before the main
position and waits for other units to arrive and build up the forces
necessary to make an assault. If opposition is encountered and the
first unit suffers attrition such that it is halted or broken (see Sec-
tion IV), the next unit in the advance stream is automatically desig-
nated as a new "first." The number of first units that advance before
the attacker evokes his set of assault decision options is a user input.

Attacker's Assault Decision Options

A user may input a sequential set of choices to define attack
plans when defenses are encountered. These may be very detailed and
elaborate. AGATE provides a decision tree of alternatives built up
from any combination of the following:

1. Initiate a bypass maneuver.
2. Shift forces to another avenue-of-advance.
3. Make a frontal assault, using any combination of tanks, APCs
    loaded with infantry, and dismounted infantry.

An attack maneuver plan is input for each avenue-of-advance and
applies to all attacks in a simulation on that avenue. An example of
one such decision tree is shown in Table 3. If the sequence (user
specified) of bypass and assault options have failed to clear a defense

Table 3

EXAMPLE OF ATTACK PLAN WHEN DEFENSES ARE ENCOUNTERED

1. Attempt a frontal assault with tanks
2. If assault fails, attempt a bypass maneuver
3. If bypass fails or is not possible, attempt a second frontal assault with dismounted infantry
4. If second assault fails, shift forces to another corridor

position and no move to an adjacent avenue-of-advance is specified, the program automatically executes a move by all units in the blocked avenue-of-advance to the avenue that has most deeply penetrated the defense.

Initiate a Bypass Maneuver. A bypass route, in our terminology, is a route within an avenue-of-advance that allows an attack unit to advance past, while remaining partially hidden from, defenders at the overwatch zone being bypassed. As mentioned in Section II, the user must input the presence or absence of bypass routes. The bypass route is not necessarily partially hidden from defenders in other zones.

When a bypass is attempted by an attack unit, the remainder of the units along the avenue-of-advance continue to move but do not advance beyond the zone from which the bypass is initiated.

A time delay occurs while the bypass unit (either tank or APC unit) moves laterally to the bypass route. Following this delay, the unit advances at a user-specified advance rate. As the unit advances around the defense overwatch position, it is assumed that the line of sight to the bypassing unit is reduced to some fraction (user specified) of the zone line of sight, and hence that the defender and the passing unit may exchange fires, but only with a reduced number of elements being seen. This advance continues (assuming that the unit has not suffered sufficient casualties to cause it to break) until the unit passes through (around) the defense overwatch zone. A minimum firing range between the bypassing unit and the defender is automatically introduced.

When the bypassing unit enters the zone to the rear of the defense, the defense units in the bypassed zone withdraw, with no exchange of fires, two overwatch zones and continue to participate in the battle. The attack units then resume the standard advance.

Shift Forces to Another Avenue-of-Advance. When this option is exercised, all units in the hills area in the avenue-of-advance in question move laterally across country to the new user-specified avenue-of-advance. A time delay is invoked in addition to the cross-country travel time from the center line of one avenue-of-advance to the center line of the new avenue. In the simulation, the move to the new avenue-of-advance is made, but the unit does not move forward until the delay-plus-travel time has elapsed. Units move laterally immediately only if they will end up at least one overwatch to the rear of the attacker's "first" unit in the new avenue-of-advance. Those forward of this point wait until this first unit in the new avenue moves closer to the defender, and then they move laterally. Units that are in the flats area proceed to the hills area and then move laterally, incurring the delay-plus-cross-country-movement time before advancing. Once a unit has waited out its time delay, it is treated as any other unit in the new avenue-of-advance.

Make a Frontal Assault. We will first discuss how the size of the assault force is determined and then how the assault force is deployed.

Sizing a Frontal Assault: When the decision is made to try a frontal assault, the question arises, "How big a force should be sent?" It is assumed that the attack commander knows, from the information gathered by the "first" unit that triggered the decision to initiate a frontal assault, the initial strength of the defender unit or units immediately in front of him. Conceptually, the attacker wants the assault force to be several times larger than the defending force so that the attack will succeed. Since the defender may have any combination of tanks, APCs, and mounted or dismounted troops, and the attack may choose any combination of tanks, APCs, and mounted or dismounted troops, the definition of "several times larger" is not clear. AGATE relies on the user to make this definition, as explained in the following paragraphs.

AGATE computes a minimum size for the assault force that is equivalent to the size of the defending force, and then increases this assault force by some user-specified multiple (e.g., 2.5, 3, 4) to obtain a force big enough to have a reasonable chance of success. With the assault force defined, we round the required numbers so that whole units (even though at reduced strength) are involved.

To compute the minimum-size assault force, the user specifies the

1. Attacker's policy mix of armor and mechanized infantry.
2. Fraction of tanks that advance (the remainder stay hull down and provide overwatching fires).
3. Fraction of APCs that advance (the remainder stay hull down and provide overwatching fires if they have mounted weapons).
4. Equivalence between dissimilar elements in the "hand-to-hand" fight that occurs when the attacker closes to the defense position, namely, (a) the number of troops equivalent to a tank and (b) the number of troops equivalent to an empty APC.

The fraction of tanks and APCs that advance reflects a policy of having some fraction of a gathered force provide overwatching fires in support of an assault. The equivalence between dissimilar elements in the close-in fight reflects what the user supposes will occur when the assault forces close with the defense forces.

Launching a Frontal Assault: The other requirement for an assault is to specify how the attack is to proceed. With a fully mounted assault, no further inputs are required. With mechanized infantry, however, the infantry can stay in their APCs unless forced to dismount enroute because of vehicle damage, or they can be dismounted in comparative safety (from direct fires) behind the overwatch zone from which the assault is launched. The user must specify what fraction of mechanized infantry is to be dismounted at the overwatch. He must also specify how the vehicles will advance in the presence of dismounted infantry. Two possibilities are allowed: (1) vehicles advance with the infantry, and (2) vehicles stay in overwatch and advance at the input cross-country rate to arrive at a user-input distance from the defense position at the same time as the dismounted infantry.

The user-specified inputs for defining and launching a frontal assault are summarized in Table 4.

Attacker's Artillery Fire Plans

The attacker's artillery batteries move as units along roads or across country. When they arrive at a point that is within one-third of their operational firing range of a defense position, they deploy and, after a user-specified time delay, commence firing at the highest currently available targets specified in the artillery fire plan. When the defense units have moved to a point where the closest defense unit

Table 4

INPUTS FOR DEFINING AND LAUNCHING A FRONTAL ASSAULT

Sizing a Frontal Assault:
- o Compute the troop-equivalent of the defense force
- o Define the desired ratio of assault forces to defense forces
- o Define the attack plan--

    Fraction of tanks that advance

    Fraction of APCs that advance

    Fraction of mechanized infantry dismounted at last hill

    Policy for advancing armor in the presence of dismounted infantry
- o Define the fraction of tanks constituting the assault strength
- o Compute the required assault force
- o Accumulate the required assault force at assembly area (last hill)

Launching a Frontal Assault:
- o No dismounted troops (e.g., armor only)--

    Initiate advance
- o Dismounted troops--

    Delay initiation to dismount troops

    Initiate dismounted infantry advance

    Start armor advance--

    To proceed slowly with troops, or

    To arrive at the defense position concurrently with dismounted infantry

is at a distance greater than two-thirds of the artillery unit's operational firing range, the artillery unit ceases firing, moves forward to the one-third range position, and begins firing again. If no targets appear on the artillery fire plan, the battery stops firing. If a higher-priority target appears, the battery shifts to that target after a user-specified time delay. Timed fires (e.g., 30 minutes of preparation fire) are permitted against main defense positions.

The attacker may define an assault policy setting up a series of as many as 13 target priorities for his artillery. As each battery completes its firing against a priority target, it is assigned the highest unassigned remaining target priority. A different set of priorities may be specified for each avenue-of-advance. Table 5 lists the artillery target options available to the attacker.

An illustrative target-priority plan is shown in Table 6. When fires are received from overwatch 3, one battery fires against overwatch 3. If the defense dismounts infantry at overwatch 3, the attacker uses airburst rounds. When the assault against overwatch 3 is completed, or that overwatch is bypassed successfully, the fires are shifted to a counterbattery. When the attacker encounters fire from overwatch 2, the fires are again shifted, etc.

Table 5

ATTACKER'S ARTILLERY FIRE PLAN TARGET OPTIONS

- o Dismounted infantry
- o Overwatch vehicles at main line of resistance
- o Vehicles at zone behind main line of resistance
- o Vehicles at a specific overwatch zone[a]
- o Counterbattery units
- o Antiaircraft units

[a]Overwatch zones in each avenue-of-advance are numbered consecutively, starting with the main defense line.

Table 6

AN ILLUSTRATIVE TARGET-PRIORITY PLAN

Priority	Target
1	Dismounted infantry
2	Overwatch 3
3	Overwatch 2
4	Overwatch at main line of resistance
5	Counterbattery units

Attacker's Air Employment Plan

The user defines the number of aircraft flights (units) and the time(s) at which they become available for assignment, as well as the number of flights allowed to be simultaneously attacking targets in the hills area and in the flats area. These two inputs allow the user to control the availability of air, as well as the traffic, in the battle area.

Targets for air attacks are defined by means of a priority table in which the user specifies a sequence of target units. Air strikes are launched against the highest priority target unit that is alive. The fraction of casualties suffered by a target unit before the aircraft seek other targets must be input by the user to limit the number of repetitive strikes against a particular target unit.

Attacker's Antiaircraft Battle Plan

Mobile antiaircraft units may be assigned to accompany ground maneuver units or to advance independently. Fixed antiaircraft units are located by the user prior to the start of the simulation.

Each antiaircraft unit is assumed to fire at aircraft units that remain in view and within range during 30 seconds of battle time. Firing is constrained by terrain masking and target detection probabilities (see Section IV). Attacker antiaircraft units in overwatch zones have one user-designated masking angle (in elevation only); those in other zones and along roads have another input masking angle.

DEFENDER'S PLANS

In each advance corridor, the defender may position maneuver units both forward of and at the main line of resistance. Artillery batteries and antiaircraft units may be positioned forward of, at, or behind the main line of resistance. Several units of any permitted types may be placed initially at any one position. With multiple corridors, the user can define defense postures that tend to cause heavy attrition to the attacker in some corridors and light attrition in others, thus making it favorable for the attacker to shift corridors and channelize the attack. Reinforcement of defense positions during a simulation is not permitted.

Defender's Maneuver Unit Battle Options

The defender's maneuver units positioned at or forward of the main line of resistance have several battle options (see Table 7). They can be instructed to (1) stay and fight until broken, (2) withdraw when the attacking force reaches the defense position, or (3) withdraw when the attacking force gets within x meters (user-defined "bugout range") of the defense position. The second option--withdraw when the attacking force gets to the defense position--is a conditional option evoked only when the attacker reaches the bugout range with a strength of less than or equal to the defender's strength, where the strength

Table 7

DEFENDER'S MANEUVER UNIT BATTLE OPTIONS

o Stay and fight until the unit breaks
o Withdraw when the attacker reaches the defense position
o Withdraw when the attacker reaches the bugout range
o Dismount infantry--
   (a) Never
   (b) All the time
   (c) At the start of the attacker's assault
   (d) When the attacker reaches a specified range from
       the defense position

of each side is measured by the number of tank and antitank weapons still functioning. This option is used as a technique to allow a defender to remain in a position when the attack has a high probability of not being able to reach the defense position.

With a mixed force (armor plus mechanized infantry) or only mechanized infantry at a position, the defender may elect to dismount infantry (a) before an assault begins, (b) when the attacker reaches a user-specified range, or (c) not at all. These options permit battle plans to be devised that can protect infantry from artillery fires at the expense of decreased infantry antitank fires against the advancing assault units.

If any defending unit withdraws, it moves back (closer to the main defense position) two overwatch positions, joining whatever forces are at that position, or to the main defense position if it is closer. It may then reengage the attacker when he attacks that new overwatch position.

Defender's Artillery Fire Plans

A defense artillery unit may be prepositioned forward of the main line of resistance in each avenue-of-advance but at least one zone behind a defense maneuver unit; or it may be prepositioned behind the main line of resistance at a standard position one-third of the unit's maximum operational firing range.

The defender may define a defense policy setting up a series of as many as 13 artillery target priorities similar to those permitted the attacker. As each artillery battery completes its firing against a priority target, it is assigned the highest unassigned remaining target priority. A different set of priorities may be made for each avenue-of-advance. Table 8 lists the artillery target options available to the defender.

Defender's Antiaircraft Battle Plan

Antiaircraft units have an automatic (i.e., built-in) policy—fire on attacking aircraft units that remain in view and within range

Table 8

DEFENDER'S ARTILLERY FIRE PLAN TARGET OPTIONS

1. Assault units attacking a defense position
2. Attacker's overwatch position just forward of the
    main line of defense
3. Back side of an overwatch position just forward of
    the main line of defense
4. A specified overwatch zone
5. Front side of specified hills
6. Back side of specified hills
7. Counterbattery units
8. Antiaircraft units
9. Units on roads in the hills
10. Units on roads in the flats

during a 30-second computational cycle. The defender's antiaircraft
units are assumed to be located where they have a clear forward view
limited only by the horizon, but where they are hidden from enemy di-
rect ground fires. Antiaircraft units may, however, be attrited by
air and artillery.

Defender's Air Employment Plan

The user defines the number of aircraft flights permitted to the
defender and the times at which they become available for assignment.
Aircraft may be assigned to strike targets only in the flats area, on-
ly in the hills area, or both. Targets for air attacks are defined
through a priority table in somewhat the same manner as for the at-
tacker (p. 21). A priority target unit is attacked by air units until
the target fraction damage specified for air strikes is reached or the
target unit is broken.

IV. INPUTS FOR OPERATIONAL CONSTRAINTS, SEARCH AND
DETECTION PROBABILITIES, AND DAMAGE FUNCTIONS

OPERATIONAL CONSTRAINTS

A series of input parameters reflect limitations on offense and
defense battlefield operations. Such parameters include more than 90
constraints that are user specified, including time delays, behavioral
constraints, and other constraints, as shown in Table 9.

The series of time delays (values specified by user) reflects ground
unit actions when the unit is the target for enemy fires or when it
changes state (e.g., dismounts infantry, organizes an attack, changes
from road to cross-country movement). Administrative delays associated
with high command actions are not explicitly included but the user may
add them by adjusting the schedule of operations.

Table 9

ILLUSTRATIVE OPERATIONAL CONSTRAINTS

Time Delays of Attacking Unit Movement Because of:
  o Air and/or artillery fires

  o Changing from road to cross-country movement;
     changing corridors

  o Setting up and retargeting artillery fire

  o Positioning for attack

  o Dismounting infantry

Behavioral Constraints:
  o Slowdown

  o Halt

  o Break

Other Constraints:
  o Reduced target-search capability due to suppression
     from enemy fires

  o Fraction of targets seen that are not real ("ghost"
     targets)

  o Attacker's rate of advance (on roads, across country,
     when suppressed)

Behavioral parameters reflect the conditions, in terms of fraction casualties, that change a unit's capability to participate in the battle. In addition to the standard "break" criterion for each class of units, tank and mechanized infantry may "slow down" their advance under fire by taking advantage of local terrain features to reduce their exposure to fire; and tank units may suffer enough attrition so that they "halt" and hence do not participate in assaults, but they may provide supporting fires from defilade positions.

Included in the class of "other" constraints are (a) reduced target-detection probabilities and rates of fire as a result of suppression, (b) fractions of detected targets that are false or ghost targets, (c) rates at which attacking units advance (on roads, across country, and suppressed), and (d) the fraction of attacker artillery that is allowed to move at any one time.

Table 10 summarizes the various changes in status that can occur for attacking armor units and antiaircraft units.

SEARCH AND DETECTION FUNCTIONS

Search and detection probabilities as functions of range are required as inputs for each sensor used (eyeball, IR, radar, etc.). They are the means used to reflect the effects of weather conditions and camouflage on the ability of an observer to detect the presence of targets.

An observer is assumed to scan a large area (zone) in a series of steps and to focus on small areas where a target might be located. Having focused on a small area, the observer attempts to detect the existence of a target within that area. The probability that an observer will include any given small area containing a target within his scan of a large area is called the search probability (P_s). The probability that an observer will detect a target after having looked at a small area containing a target is called the detection probability (P_d). The detection probability is the measure of the observer-to-observer variation in ability to detect targets for a fixed set of parameters (e.g., range, target type, weather conditions, camouflage, etc.), and may limit firing opportunities for weapon systems.

Table 10

WHAT CAN HAPPEN TO ADVANCING ARMOR OR ANTIAIRCRAFT UNITS

In Assembly Area:
o Delay until input separation distance from preceding unit on road is achieved

o Break from air attack

On Road in Flats:
o Delay until input separation distance from preceding unit on road is achieved

o Stop during air attack and delay

o Button up and slow down during artillery attack

o Attrit to "slowdown" speed--unit abandons attack

o Attrit to "break"--unit abandons attack

On Road in Hills:
o Delay until input separation distance from preceding unit is achieved

o Move to new avenue-of-advance

o Deploy across country if "first" unit and fired at

o Deploy across country one overwatch behind "first" unit

o Stop and delay for air attack, then deploy across country

o Deploy across country when attacked by artillery

o Attrit to "slowdown" speed--unit moves across country

o Attrit to "break"--unit abandons attack

Across Country in Hills:
If "first" unit--
o Delay at each overwatch, reconnaissance by fire against next overwatch if attrited

o Advance until halted or broken

o Lead "bypass" at reduced speed

o Attrit to "halt"--new "first" unit defined

o Attrit to "break"--unit abandons attack

o Button up for air, artillery, direct fires

If not "first" unit--
o Delay at one overwatch behind "first"

o Delay for assault assembly

o Delay to dismount infantry

o Delay for "bypass"

o Attrit to "slowdown" speed

o Attrit to "halt"--unit advances to next overwatch; provides covering fire

o Attrit to "break"--unit abandons attack

o Move to adjacent corridor

o Button up for air, artillery, direct fires

In an Assault:
o Move at constant speed

    (a) At same speed as dismounted troops if accompanying infantry

    (b) At standard cross-country speed if only armor is present or if catching up with dismounted infantry

o Attrit to "break"--unit abandons attack

DAMAGE FUNCTIONS

The probability of kill (P_K) as a function of range is required as an input for each direct-fire weapon versus vehicle combination (ground-to-ground, air-to-ground, and ground-to-air). These basic data should reflect combat rather than test operations. As used in the program, these P_K's reflect the probability that a target is killed or is out of action (e.g., total of mobility, firepower, and K-kill). In addition, an associated fraction of K-kills is required as an input to reflect the fraction of killed targets that are recognizable as being killed and hence do not receive additional fires. These P_K versus range functions are internally converted to a single average P_K within each zone from a firing position to reduce the computational burden.

The data may reflect multiple-shot bursts or single-shot P_K's. The value is intended to reflect the P_K for a single weapon firing against a single target in one 30-second time interval. Aimed fire by one firing element against two or more targets in this interval is not permitted.

The fraction of casualties to a unit from each type of artillery volley or air-delivered area munition is required as an input for vehicle and dismounted infantry targets.

V. EXECUTION

In AGATE there are nine generic types of firing elements (see Table 1). Each of them may fire at some of the seven generic types of targets listed in Table 1 if conditions permit. Within each generic type there may be several particular types (e.g., M-60 tanks firing 105-mm main guns, T-62 tanks firing 155-mm main guns, APCs firing TOWs, BMPs firing 75-mm guns). Direct-fire weapons (tanks, APCs, infantry antitank) may exchange fires. Artillery may engage in counterbattery fire as well as deliver fires against direct-fire weapons and deployed infantry. Aircraft can deliver fires against all target types except other aircraft (air-to-air battles are not included). Antiaircraft weapons may fire only against aircraft. When a mounted infantry unit dismounts, sub-units are formed in addition to the APC unit: one infantry unit, one or two (user-specified) antitank weapon units, and one mortar unit. The dismounted infantry unit may exchange fires only with other infantry. The infantry antitank-weapon units may exchange fires with tanks or any ground unit firing antitank weapons. Mortars may fire at tanks, APCs, antiaircraft vehicles, infantry, and infantry antitank units.

In the following discussion, we outline (a) the exchange of fires between direct-fire ground weapons, (b) air-to-ground firings, (c) artillery fires, (d) mortar fires, and (e) infantry versus infantry fires.

Each weapon may fire during a 30-second interval. At the end of each 30-second integration cycle, all unit strengths are updated.

INITIATION OF DIRECT-FIRE EXCHANGES (See Table 11.)

An exchange of fires between attacking and defending ground units are initiated during each 30-second integration cycle if

1. A defense unit sees advancing vehicles.
2. A defense unit chooses to fire at an attacker's smoke or to flash signature fires from the previous cycle.
3. An attacking "first" unit attempts to draw the defender's fire by firing a few rounds at suspected defense positions on the next-most-forward hill (reconnaissance by fire).

Table 11

GROUND-TO-GROUND DIRECT-FIRE EXCHANGE

1. *Defenders see advancing units*:
   Defenders that see advancing units, fire.

   Attackers that see defenders' fire signatures, return fire.

   Defenders that have not fired and see attackers' signatures, return fire.[a]

2. *Defenders see attackers' second-fire signatures from a previous cycle*:
   Defenders that see a signature from a previous cycle, fire.[b]

   Attackers that see defenders' signatures, return fire.

   Defenders that have not fired and see attackers' signatures, return fire.[b]

   Attackers that have not fired and see defenders' signatures from a second fire, return fire.

3. *Attackers reconnoiter next overwatch by fire*:
   Attackers fire at overwatch.

   Defenders that see attacking signatures, return fire.[c]

   Attackers that see defending signatures, return fire.

[a]If defense fire against signatures is permitted when visible targets are present.

[b]If defense fire against signatures is permitted.

[c]If defense return of reconnaissance is permitted.

Defense forces always fire at any visible attack vehicles within firing range. Attack forces always fire at seen smoke or flash signatures from defense fires. The defender's forces may, at the user's option,

1. Not fire at signature targets.

2. Fire at signature targets seen and in range.

3. Fire at seen and in-range signature targets when the defender has fired at visible targets, and signature fires are returned.

4. Fire at seen and in-range signature targets when the attacker is reconnoitering by fire.

The purpose of allowing the defender these firing options is to reflect tactical considerations. In an exchange of signature fires between attacker and defender, the defender does not generally have the kill probability advantage that he does when firing at visible targets from a defilade position. In addition, since the defender is usually outnumbered, he may be subjected to massed fires when he exposes himself by firing.

The attacker, on the other hand, seeks to draw fires to determine the defense positions. In AGATE, the attacker reconnoiters the next-most-forward hill by fire.

The most forward or "first" attacker unit in each corridor advances from overwatch to overwatch, seeking out defense units. It advances without slowdown until it has received casualties. Once casualties have been accrued, the unit advances only after it has taken time to observe the next overwatch and fire a few rounds at the overwatch position. This reconnaissance by fire may or may not be returned by defense fires from any defender observing the fires; in either case, the "first" attacker unit advances toward the position.

TARGETING IN DIRECT-FIRE EXCHANGES

Visible and signature targets may be seen in several zones in one 30-second battle interval. The question immediately arises, At which target should the unit fire? For fires by the defender against visible targets, AGATE assumes that the fires are directed against targets in the zone closest to the defending unit (in any avenue-of-advance) that contains visible targets. This assumes that the closest visible target represents the greatest threat and must be dealt with first.

Attacker and defender targeting of signature targets is dealt with in a more general manner. When firing against signature fires seen in several zones, both attacker and defender have several fire allocation alternatives. They can (a) allocate all fires against elements in the closest zone, (b) allocate fires in proportion to the number of signature fires seen in each zone, and (c) allocate fires proportional to the kill potential, where kill potential is defined as the expected number of targets killed, assuming that there are enough targets present for each firer to fire at a separate target. Operationally, fires tend to

be directed against targets that are closest and hence represent an immediate threat. However, if a main body (e.g., many fires) is observed at longer range, some fraction of fires tends to be allocated to this group.

To reflect these operational concepts, the following allocation policy is used in AGATE to weight the allocation of fire to satisfy, if possible, the fire requirements of the nearest zone before allocating firers to more distant zones: The number of firers allocated to each zone is the minimum of

1. Number of firers that see targets in several zones but have not been assigned a target zone.
2. Number of firers that see targets in the zone.
3. Number of firers that satisfy the kill-potential requirements of the zone.

For example: Assuming that 20 firers see targets in several zones but have not yet been assigned a target zone, that 10 of these see targets in the zone in question, and that 5 firers are required to satisfy the kill potential of the zone, then 5 fires would be allocated to the zone.

COMPUTATIONAL SEQUENCE OF DIRECT-FIRE EXCHANGES

Both the attacking units and the defending units may exchange fires in any 30-second computational cycle. The exchange of fires within a 30-second cycle may be initiated by a defending unit if elements of the unit detect visible targets. The exchange may also be initiated by a defender observing attack signatures in the previous cycle or by an attacking unit reconnoitering the next hill with fire. These firing sequences are listed in Table 11.

The sequence of fires when a defending unit sees advancing vehicles is illustrated in Fig. 5. When the attacker's vehicles are within the line of sight of a defending unit, the number of elements within the defending unit that see at least one vehicle, fire at a vehicle. The number of attacking elements that are within line of sight of the

DEFENDER

1. Fires at visible
   attacker targets

3. Elements not firing in
   (1) fire at attacker's
   signature fires

ATTACKER

2. Fires at signatures
   of defender's fires

4. Elements not firing in
   (2) fire at signatures of
   defender's fires in (3)
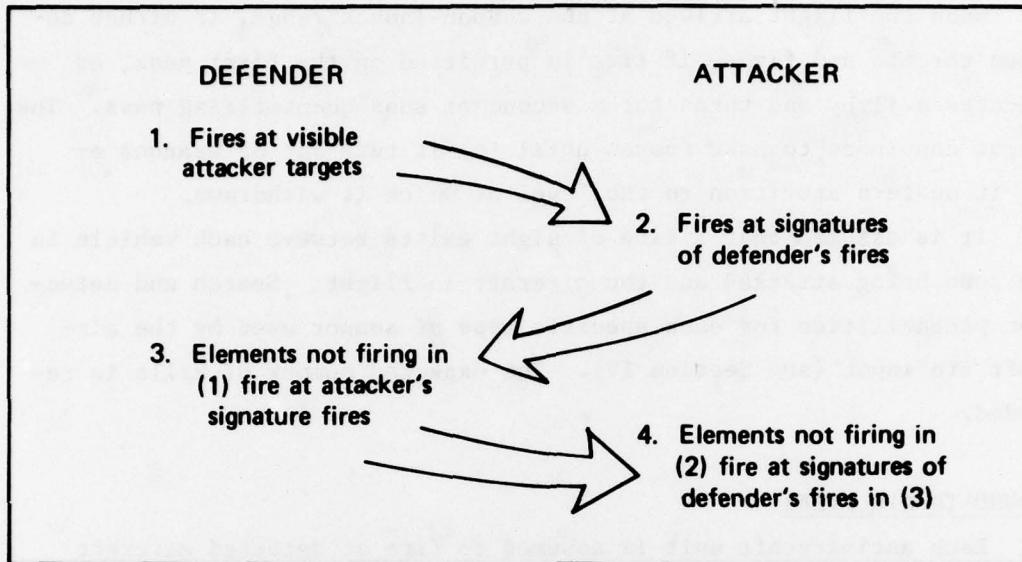
Fig. 5 — Exchange of direct ground-to-ground fires
(sequence 1 — defender "sees" advancing unit)

defender, and that see the signature of the defender's fire, fire at
the signature if permitted to do so. In like manner, the attacking
elements that did not see the first defense signature but see the sec-
ond defense signatures, fire at the defender's second signatures.

Fire exchange sequences 2 and 3 evolve similarly.

ARTILLERY FIRES

Artillery fires by volleys against targets defined in the artillery
fire plan. The fraction kill for all volleys fired during a cycle is
computed assuming that all volleys are aimed at a defined target area
(e.g., company). The zone fraction kill is computed by averaging the
fraction kill over all units in the zone.

AIR-TO-GROUND FIRES

When an air unit becomes available for assignment, it flies at the
defined penetration altitude toward the zone in which its assigned tar-
get is located.

When the flight arrives at the weapon-launch range, it either detects targets and fires, if fire is permitted on the first pass, or executes a flyby and turns for a second or subsequent firing pass. The flight continues to make passes until (a) it runs out of weapons or (b) it suffers attrition to the level at which it withdraws.

It is assumed that a line of sight exists between each vehicle in the zone being attacked and the aircraft in flight. Search and detection probabilities for each specific type of sensor used by the aircraft are input (see Section IV). The expected number of kills is recorded.

GROUND-TO-AIR FIRES

Each antiaircraft unit is assumed to fire at detected aircraft that are within range for the entire 30-second interval. Mobile antiaircraft units advancing with the attacking force may be moving along roads or advancing across country, in which cases the line of sight to aircraft may be screened. It is assumed that antiaircraft units do not have their target detection probability reduced when they are receiving fire. All antiaircraft units that meet the fire conditions are assumed to stop momentarily if they are advancing and then to fire at aircraft they see.

CONSOLIDATION OF KILLS

The expected number of targets killed in each zone by a particular firing unit during a 30-second interval is the expected number of targets killed in the zone *if no other firing units have fired into the zone*. If several different units--maneuver, artillery, mortars, or air--fire into the same target zone, the effects of overkill must be eliminated to determine the expected number of targets killed in the zone. Under these conditions, the expected number of targets killed and attributable to each unit is less than would have been attributable to the unit if it alone had fired into the zone.

The technique for computing the expected number of targets killed in a zone is straightforward: (1) calculate, separately, the zone survival probability from each unit's fires, (2) compute the overall

zone survival probability as the product of the zone survival probabilities from each unit's fires, and (3) compute the kills and remaining strength of each target unit in the zone.

The number of kills attributed to each firing unit is then the number of targets killed times the ratio of (a) the expected number of targets killed by the firing unit if no other units fired into the zone to (b) the sum of the expected number of targets killed by each of the units firing into the zone, assuming that each unit was the only one firing into the zone.

END GAME IN AN ASSAULT (See Table 12.)

When an attacking force advances to the defense's bugout range, the defender may choose to withdraw. If the defender withdraws, all defense units in that zone withdraw (if not broken) back two overwatch positions toward the main line of resistance or to the main line of defense if it is closer. The attacker's tank and mounted mechanized infantry units, if not broken in the assault, rejoin the attacking stream of units in the avenue-of-advance. Dismounted infantry units, although not necessarily broken, are assumed to no longer participate in the battle because of the time required to regroup.

If the defender chooses to stay and fight, the advance continues until the attacker reaches a nominal 100 meters from a defender. Air and artillery are shifted to other targets and the hand-to-hand fight or end game is calculated.

In many combat situations, either the attacking units or the defending units will have been broken by the time that the attacker closes to the defender's position. Attacking infantry closes with the armor and joins the end game.

We are not aware of any well-defined model that describes the fire exchange among tanks, APCs, and infantry when the forces meet in a defense position and engage in a hand-to-hand fight. In lieu of such a model, a vehicle-troop equivalent is computed and used as an index of the strengths of the attacking force and defending force that engage in the hand-to-hand fight. A vehicle-troop equivalent is the number of infantry troops that are expended in destroying a vehicle such as

Table 12

END GAME: DEFENDER WITHDRAWS DURING AN ADVANCE

Attacker:
  o Tank units, not broken, rejoin attacker's stream of units
    in avenue-of-advance.

  o Mechanized infantry, not dismounted and not broken, rejoin
    attacker's stream of units in avenue-of-advance.

  o Dismounted infantry units are removed from simulation.

Defender:
  o All units in attacked zone withdraw two overwatch positions
    or to main position if that position is less than two
    overwatch positions from the attacked zone.

  o Broken units are removed from simulation.

a tank or APC (e.g., 10 troops expended per tank destroyed, 6 troops
expended per APC destroyed). The difference in vehicle-troop equiv-
alents for each side is used to determine which side has vehicles left
and how many infantry troops of the opposing side must be expended to
destroy those vehicles. If unbroken infantry units remain on both
sides, the outcome of a small-arms firefight is computed.

This process leads to one of several possible outcomes. If the
attacker's armor (tanks and/or infantry mounted in APCs) remains, un-
broken armor units rejoin the attacker's advancing stream of units
after a time delay, but deployed attacking infantry no longer partic-
ipates and is withdrawn from the simulation. The defender's forces
in the zone are removed from the simulation. If defending armor re-
mains, (a) unbroken units (armor and infantry) retain the position and
continue to block the attacker advance, and (b) attacking units that
arrived at the defense position are removed from the simulation. The
winner of the end game and what the winner does are summarized in
Table 13.

THE INFANTRY FIREFIGHT

The outcome of an infantry firefight (winner, and casualties to
each side) is computed from a set of equations that match the solutions

Table 13

END GAME: DEFENDER STAYS AND FIGHTS

Residual Forces					
Attacker		Defender		Firefight Winner	Situation
Armor	Infantry[a]	Armor	Infantry		
x	x	--	--	Attacker	Armor may continue in battle.
x	--	--	--	Attacker	Armor may continue in battle.
--	x	--	--	Attacker	No units continue in battle.
--	--	x	x	Defender	May retain position.
--	--	x	--	Defender	May retain position.
--	--	--	x	Defender	May retain position.
--	x	--	x	As computed	If the attacker breaks before reaching the defense position, the defense retains the position and the attacker is removed from the simulation. No units continue in battle if the attacking infantry advances into position.

[a]Mounted or dismounted.

developed from the Fast-Val study.[3] Comparisons of Fast-Val solutions with detailed data on several firefights that occurred during the war in Vietnam suggest that these results are reasonable. These equations assume that the TO&E mix of small arms and machine guns for each side remain approximately fixed (e.g., infantry units do not change drastically from their Vietnamese composition). An attacking unit is assumed to make its final assault only if it has accrued fewer than 23 percent casualties. The loser of the firefight in Fast-Val is determined by which force reaches its break point first (30 percent for attacker units, 50 percent for defender units). If the attacker breaks before he reaches the defender's position, the defender is assumed to retain the position and the broken attacker is removed from the simulation. If the attacker reaches the position, the winner of the fight is

determined from the Fast-Val equations. In this case, mopping up con-
sumes time and exhausts resources, neither the winner nor the loser
can regroup and continue as a fighting unit, and both forces are re-
moved from the simulation.

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